AN INTEGRATED ENERGY PLAN
FOR THE STATE OF GUJARAT

Report Submitted to

THE GUJARAT ELECTRICITY BOARD, BARODA

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PREFACE

This study commissioned by the Gujarat Electricity Board and conducted by the Tata Energy Research Institute represents a major innovation in energy planning, wherein a long term perspective has been developed for a major state of the Indian Union. While several elements of energy planning are dealt with at the state level, essentially energy policies and plans have been evolved in the past only at the Centre. It is perhaps for the first time that an integrated energy plan has been developed in this study on a rigorous quantitative basis at the state level.

Energy Planning should lead to investment decisions, many of which are related to long gestation projects. Hence, despite uncertainties of forecasting, it is important for a State Government to evaluate strategies and directions extending at least 20 years into the future. Often changes in policies require suitable debate and discussion with actions that lag such dialogues by several years. In the case of Gujarat, for instance, our study clearly brings out some changes in priorities, fuel mix and technology that need to be grasped early if the State's economy is to grow at a healthy rate upto the year 2010. This report has been prepared through a blending of academic skills and inputs from policy makers. We hope this example of close interaction would be carried further not only in the state of Gujarat but perhaps emulated in other states of the country. We are indeed grateful to the leadership of the GEB for giving us this opportunity, which reflects the enlightened approach that the board is following in meeting its future challenges.

- R.K. PACHAURI
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EXECUTIVE SUMMARY

The total population in the state of Gujarat, according to the 1981 population census, was 3.41 crores of which 2.35 crores (68.9%) lived in rural areas and 1.06 crores (31.1%) lived in urban areas.

The agriculture sector is a significant contributor to the state income with a share of about 35 to 40% of the state income. More than 60% of the working population depends on agriculture and allied activities for their livelihood. The main food crops of the state are sorghum, paddy, maize and wheat. The main commercial crops are cotton, groundnut, tobacco and sugarcane.

Till 1960, the industrial economy of the state consisted primarily of the textile industry and engineering industries that were essentially ancilliaries to the textile industry. The discovery of oil and gas and the setting up a refinery at Koyali acted as a landmark in the industrial development of the state. The state is now a major producer of petro-chemicals, fertilizers, common salt, diesel engines and pharmaceutical formulations.

Per capita consumption of electricity in Gujarat increased from 138 KWh in 1970-71 to 294 KWh in 1985-86 - this can be compared with an average per capita consumption at the all India level of 176 KWh. Total coal consumption in 1986-87 is estimated at 10.63 million tonnes of which nearly 70% is consumed by the power sector. Present consumption estimates place coal demand at approximately 12 million tonnes and it is felt that infrastructure availability will act as a major constraint on the growth of coal consumption in the future. Gujarat also has a very high consumption of petroleum products at 132.2 Kgs. per capita against an all India average of 59.3 Kgs. per capita.

A linear optimisation model was set up to estimate end-use energy demands relating to specific rates of growth of different sectors of the economy as well as population growth. The objective of the model that has been set-up is to minimise total energy system costs for meeting these end-use energy demands. Factors that effect the solution of this model include cost of energy production, cost of conversion, cost of transmission and distribution, efficiencies of conversion transportation and utilisation and end-use device costs.

While the reference year for the study had been taken as 2010, energy demand estimates have been made for the years 1994-95 and 1999-2000 as well. A summary of these demands is given below :

	1994-95	1999-2000
Peak Load (MW)	4271.0	7228.0
Electricity requirements at bus-bar (GWh)	24320.0	41160.0
Non-coking coal	20.0	31.68
Natural gas (MMSCMD)	5.0	17.29
Petroleum Products (MT)	6.26	6.35

This model was run for the year 2010 and the assumptions that were made are listed in Chapter III of the report. Population for the year 2009-10 was taken as 5.19 crores. Sectoral growth rates were by and large based on past trends in sectoral growth. Likely benefits from major projects such as the Sardar Sarovar Project has been taken into account explicitly.

The base case model for the year 2009-10 was run assuming that coal and gas availability is not constrained. Thermal capacity had been assumed at a minimum of 4392 MW which is the capacity that has already been sanctioned/cleared. The growth rates that have been assumed for different sectors are listed in Table 12 in Chapter III.

Under this scenario total electricity demand at the bus-bar works out to 57.1 TWh. Peak load at the bus-bar works out to 10026 MW. The Thirteenth Annual Power Survey estimates energy requirements in 2004-05 at 54.42 TWh and peak load for the same year at 10057 MW.

Coal demand at 31.8 million tonnes implies an average annual rate of growth of 4.7%. Natural gas consumption requirement works out to 31.1 million cu.m./day and petroleum products to 5.94 million tonnes per annum.

Industry accounts for 43% of total electricity demands, households for 23% and agriculture 18%. Of the coal consumed 64% is for providing process heat to industry and the balance for power generation. 31% of petroleum products are consumed by the transportation sector and 35.4% by industry. Middle distillates account for 60% of the petroleum product consumption.

A summary of the results that have been obtained from the model by varying key assumptions are presented below:-

Scenario I :

Assumptions : (i) Availability of coal restricted to 20 million tonnes/annum due to perceived transportation capacity limitations.

(ii) Natural gas availability restricted to 10 million cubic metres per day.

Results :

- Peak load drops to 8000 MW. Gas based capacity reduces to 1632 MW while thermal capacity increases to 7320 MW.
- Irrigation energy demands are being met wholly through the use of diesel pumpsets.
- The total HSD demand increases to 3.88 MT - signifying a demand 2.55 MT higher than Gujarat's allotted share in 2010.
- Coal use by industry is substituted by increased fuel oil consumption (5 MT)
- Total petroleum product consumption increases by 140%.
- Natural gas use in the domestic sector is replaced by

increased kerosene consumption

- A grid connected wind power generation of 1.31 TWh is indicated.

Conclusions : With the availability of gas constrained to 10 million cubic metres per day, natural gas demands of the fertilizer sector are met first followed by demand by the power sector. Additional coal based generating capacity is indicated only due to the lowered gas based generation. For industrial process heating, coal emerges as the desired fuel and is replaced by fuel oil only due to the constraint on its availability.

Scenario II :

Assumptions : While keeping the supply of coal unrestricted the availability of gas alone has been constrained to 10 million cubic metres/day.

Results :

- Consumption of coal goes up to 50 million tonnes - the power sector accounting for nearly 29 million tonnes.

- Thermal capacity requirements increased to 10731 MW.

- Freight transportation requirements increase by 17.5% over the base scenario requirements.

Conclusions : If adequate supplies of natural gas are not made available to Gujarat, the demand for coal will be unsustainably high. Enormous resources would have to be diverted to infrastructure development to permit the movement and handling of this quantity of coal. The consumption of this quantity of coal would also raise issues relating to pollution of the environment, increased maintenance costs relating to the declining coal quality etc.

Scenario III :

Assumptions : While natural gas availability is unrestricted, coal consumption is restricted to 20 MT/annum.

Results :

- Peak load declines marginally to 9779 MW and electricity demand to 45660 GWh.

- Natural gas demand goes up to 39.6 million cu.m./day of which 9.41 million cu.m./day are consumed for industrial process heating.

Conclusions : Given a constraint on the infrastructural capacity to move coal, the natural gas requirements of the state would be in the range of 40 million cu.m/day in order to sustain economic growth rate of 5% per annum. Of this 24.9 MMSCMD as a fertilizer feedstock and 9.41 MMSCMD by industry to meet its process heat requirements. Coal thus comes out as the first option for meeting process heat requirements followed by natural gas. Fuel oil is used only in the situation where both the above fuels are constrained.

Scenario IV :

Assumptions : In this scenario we have assumed that domestic crude oil production would reach the level of 75 MT by the year 2010. Under this scenario, at the national level, refining output would be about 70 million tonnes which has been incorporated in the model for Gujarat.

Results :

- Consumption of firewood declines from about 2 million tonnes per annum to about .28 MT.
- Consumption of diesel for irrigation increases by about 50% to .616 MT substituting for approximately 650 GWh of electricity.
- Consumption of LPG goes up by 7% and of kerosene by nearly 14%. Total petroleum product consumption increases by nearly 8%.
- Electricity demand at the bus-bar declines marginally as does peak load (9866.2 MW)

Conclusions : To the extent that additional diesel is available from domestic refineries it is more economical to use diesel for irrigation rather than electricity. Also LPG and kerosene that are made available from the domestic refineries provide a better option as compared to firewood for meeting household energy requirements.

Scenario V :

Assumptions : No major improvements are likely to take place in transmission and distribution efficiences. Thus T&D losses in 2010 are taken to be 24% as against 18% in the base scenario.

Results :

- Peak load at bus-bar increased to 11278 MW
- Gas based generation capacity would have to be increased to meet the larger generation requirements.
- Natural gas demand by the power sector goes up from 25.81 MMSCMD to 30.46 MMSCMD.

Conclusions : If immediate attention is not given towards cutting down of line losses, much larger capacity would have to be set up to meet electricity requirements. While this conclusion is to be expected the purpose of this run is to determine the demand for natural gas under such a situation.

Scenario VI :

Assumption : The average lead distance for coal movement has been increased from 800 Kms to about 1200 Kms.

Results :

- Non-coking coal consumption declines marginally to 30.94 MT from 31.77 MT. This decline is due to a lower level of consumption by the industrial sector.

- The increased freight transportation requirements result in an increased demand for diesel. However, diesel consumption for irrigation is substituted by electricity.
- Total electricity demand goes up by about 3% and natural gas demand increases to 32.26 MMSCMD from 31.1 MMSCMD due to the increased demand from the power sector.

Conclusions : As the lead distance for coal increases the use of natural gas also increases. Diesel use in irrigation is substituted for by electricity and coal use for process heating is substituted for by the less transport-intensive fuel oil.

Scenario VII

Assumptions : Efficiency improvement in energy use in industry of 20-30%.

Results :

- Decline in peak load to 8800 MW and in generation to 50057 GWh.
- Demand for coal reduces to 27.2 MT due to lower process heat requirements
- Natural gas requirements reduces to 21.23 MMSCMD

Conclusions : A study by GEDA had estimated efficiency improvements of 20-30% in industries of Gujarat with payback periods ranging from 8-18 months. In a state faced with a severe energy crisis the above scenario brings out the extent to which conservation efforts would help in reducing demand. Other measures such as improved lighting technologies have not been considered in this run but would have a significant impact on peak load requirements.

Scenario VIII

Assumptions : The rate of growth of electric traction capacity restricted to 5% instead of 8%.

Results :

- Non-coking coal consumption declines marginally from 31.77 MT to 30.95 MT
- Fuel oil consumption increases by 40% to 714'000' Tonnes.
- The reduced electric traction capacity results in demand for road freight traffic increasing by about 38.5%. Deisel demand for transportation increases to 2.32 MT.

Conclusion : Coal is the preferred fuel for meeting industrial process heat requirements. However, if transportation infrastructure is a constraint then a shift takes place towards the use of fuel oil for meeting industrial energy demands. Consumption of coal is reduced only marginally. The pressure on road transport would increase tremendously if railway capacity is inadequately developed.

Scenario IX

Assumptions : Coal, fuel oil and natural gas based cogeneration options have been considered for relevant industries.

Results :

- 916 MW of coal based and 995 MW of natural gas based cogeneration capacity is indicated.
- System electricity demand and peak load drops to 34263 GWh and 6017 MW respectively.
- While coal consumption declines only marginally to 29.08 MT, demand for natural gas drops significantly to 22 MMSCMD.

Conclusion : Alongwith a concerted drive towards energy conservation, energy crisis the cogeneration option should be encouraged as far as possible. The above scenario indicates a reduction in total primary energy demand of approximately 15%. Coal and natural gas emerge as the preferred options for meeting the cogeneration requirements. However, if the movement of coal is a constraint on the system then the demand for natural gas would increase.

Scenario X

Assumptions : The rate of growth of State Domestic Product would average at 6% per annum.

Results :

- Peak load and energy requirements at the bus-bar work out to 14282 MW and 81.32 TWh respectively.
- Demand for natural gas increases to 47 MMSCMD of which 41.5 MMSCMD are used by the power sector.

- Demand for non-coking coal goes up to 41.75 MT per annum of which nearly 31 MT are demanded by the industrial sector.

Conclusions : Installed capacity requirements in the year 2010 would be close to 18,000 MW. This would require an additional average capacity of about 3000 MW to be set up in each five year plan period upto the year 2010. Actual capacity additions that are likely to take place in the Seventh plan period are in the range of 1500 MW. A large quantity of natural gas would have to be allotted to the state of which the power sector would be the major beneficiary. Demand for non-coking coal is extremely high at 42 MT. However, infrastructrual constriants may require its substitution by either natural gas or fuel oil. While the former would further raise the share of Gujarat in the consumption of natural gas in the western region the latter would imply high costs in terms of foreign exchange outflows. There is a clear case for vigorous efforts to improve efficiency of the T&D system in the state and in the major energy consuming sectors of the state's economy.

CHAPTER I : Gujarat Economy in Brief

1.0 General

Amongst the states of India, Gujarat ranks tenth in respect of population and ninth with respect to area. The density of population in Gujarat in 1981 was 174 persons per square km as against a density of 216 persons per square km for India.

The total population in the state of Gujarat, according to the 1981 population census, was 3.41 crores of which 2.35 crores (68.9%) lived in rural areas and 1.06 crores (31.1%) lived in urban areas. Thus the degree of urbanisation in Gujarat is much higher than the Indian average which is about 23.3% The mid year population in 1987 has been estimated at 3.84 crores.

The state income of Gujarat in 1985-86 has been estimated at Rs.10379 crores (current prices) and works out to a per capita income level of approximately Rs. 2775 as against an all India average of Rs. 2344 per capita.

The sectorwise description of the Gujarat economy is provided below in brief.

1.1 Agriculture

The agriculture sector is a significant contributor to the state income with a share of about 35 to 40% of the state income. More than 60% of the working population depends on agriculture and allied activities for their livelihood. The Land Utilisation Statistics (1980-81) show that in Gujarat 53.75% of the reported area of 188.3 lakh hectares is under cultivated crops. Approximately 29.9% of the agricultural holdings are irrigated - either partially or wholly. The wholly irrigated holdings account for 35.1% of the total irrigated area the balance being partially irrigated. Table 1 gives a break-up of area irrigated by source of irrigation.

Table 1.

	%
Surface wells	66.0
Canals	18.3
Tubewells	12.6
Tanks	2.7
Others	0.3

The main food crops of the state are sorghum, paddy, maize and wheat. The main commercial crops are cotton, groundnut, tobacco and sugarcane. The state accounts for 18% of the total cotton area and 28.1% of the total groundnut area in the country (1983-84). Table 2 brings out the changes in production and yield of different types of crops over the five year plan periods.

1.2 Industry

Gujarat employed a productive capital of Rs. 5306 crores (1982-83) as against an all India level of 57326 crores. Till 1960, the industrial economy of the state consisted primarily of the textile industry and engineering industries that were essentially ancilliaries to the textile industry. The discovery

ble 2: Average, Area, Production and Yield Per Hectare of Important Crops During Different Plan Periods - Gujarat

Area in lakh hectares
Production in lakh tons/Yield in kgs/ha

an period	Unit	Food-grains	Oil-seeds	Cotton	Tobacco	Sugar-cane
rst plan	Area	55.86	11.93	13.72	0.60	0.10
51-52 to 1955-56	Prod.	18.75	4.40	8.83	0.41	0.57
	Y/H.	336.00	362.00	109.00	683.00	5182.00
cond plan	Area	49.80	18.99	17.50	0.81	0.18
56-57 to 1960-61	Prod.	20.28	11.07	11.17	0.56	0.94
	Y/H.	407.00	586.00	108.00	691.00	5222.00
ird plan	Area	47.96	23.44	17.57	0.86	0.29
61-62 to 1965-66	Prod.	25.79	13.58	15.23	0.83	1.65
	Y/H.	538.0	581.0	147.0	965.0	55.94
erage of three Annual	Area	51.90	21.57	16.89	0.91	0.33
ans-1966-67 to 1968-69	Prod.	28.11	11.31	15.48	0.93	1.81
	Y/H.	542.00	524.00	156.00	1026.00	5476.00
urth plan	Area	51.82	20.56	19.65	0.88	0.46
69-70 to 1973-74	Prod.	37.19	13.87	20.18	1.13	2.53
	Y/H.	714.00	675.00	174.00	1284.00	5500.00
fth plan	Area	47.44	22.07	18.58	1.00	0.62
74-75 to 1977-78	Prod.	35.72	18.64	17.93	1.57	4.22
	Y/H.	753.00	844.00	164.00	1574.00	6806.00
erage of two Annual	Area	49.05	24.96	17.69	1.24	0.82
ans-1978-79 and 1979-80	Prod.	44.45	21.04	19.70	2.11	6.86
	Y/H.	906.00	842.00	189.00	1702.00	8366.00
xth plan	Area	48.83	26.28	14.98	1.16	0.95
80-81 to 1983-84(4 yrs)	Prod.	50.46	22.27	17.06	1.96	6.84
	Y/H.	1033.00	847.00	194.00	1690.00	7193.00
86-87	Area	41.43	23.48	13.66	1.10	0.69
	Prod.	30.89	16.68	10.93	1.83	5.57
	Y/H	745.60	710.39	136.02	1663.64	8072.46

te: 1. Production of sugarcane is in terms of Gur.
2. Production of cotton is in lakh bales each of 170 kgs. lint.
3. Total oilseeds include groundnut, sesamum, castor, rape and mustard.

of oil and gas and the setting up of a refinery at Koyali acted as a landmark in the industrial development of the state. The fertilizer complex of GSFC, petro-chemical complex of IPCL and a large number of other major projects were set up in Gujarat soon after this. The share of chemical and allied items produced in the state is now around 14% of total national production and this is expected to increase to about 23% by the end of the Seventh Plan period. The state is a major producer of petro-chemicals, fertilizers, common salt, diesel engines and pharmaceutical formulations. Table 3 gives the outputs of some major products manufactured in Gujarat.

Table 3: Some Major Products Manufactured In Gujarat - 1986

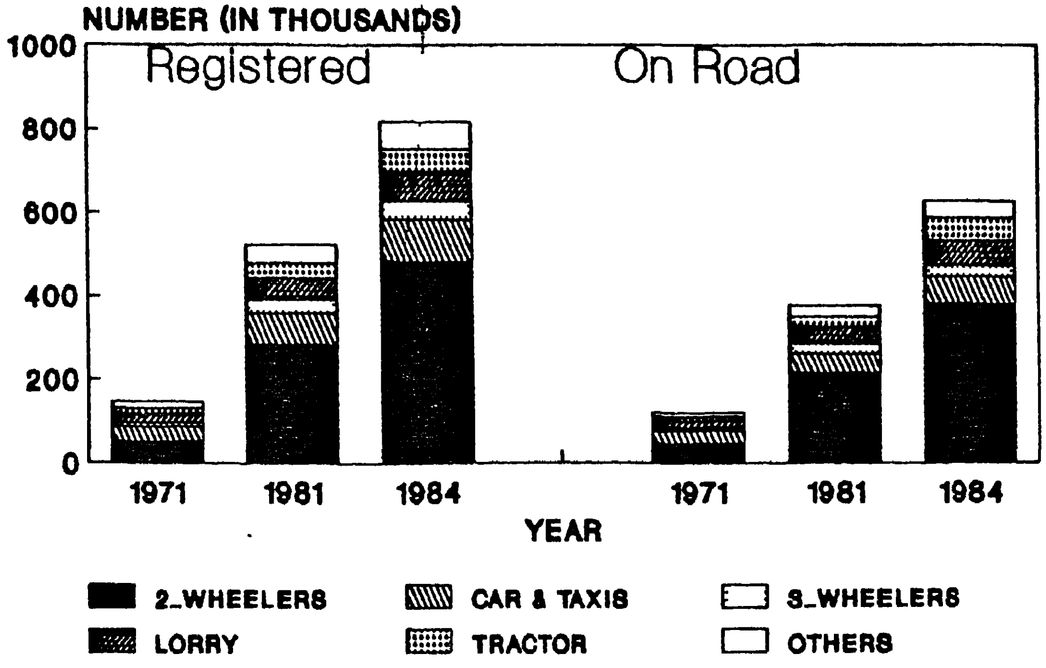
Item	A/C Unit	Production	% Share in All-India Production
Sugar	'000 T	470	6.7
Cement	'000 T	2390	6.8
Vanaspati	'000 T	67	7.4
Paper & Paper Board	Mill.T.	0.6	3.8
Vat Dyes	Mill.kg	0.6	3.5
Cotton Yarn	Mill.kg	124.0	8.3
Sulphuric Acid	'000 T	345.0	12.3
Dry Batteries	Mill.Nos.	23.0	19.6
Caustic Soda	'000 T	345.0	12.3
Nitrogenous Fertilizer	'000 T	946.0	19.6
Viscose Filament Yarn	'000 T	13.0	29.5
Cotton cloth	Mill.mtr	581.4	17.4
Phosphatic Fertilizer	'000 T	536.0	33.5
Polyester Filament Yarn	M.T.	15353.0	19.3
Salt	Mill.T	6.5	65.8
Azo dyes	Mill.kg	1.5	72.2
Naphthols	Mill.kg	0.8	51.3
Sulphur Black	Mill.kg	1.2	73.3
Soda Ash	'000 T	848.0	97.0
Iodised Salt	'000 T	200.0	57.0

Source: Office of the Industries Commissioner, Gujarat State, C.M.I.E. - Various Issues.

1.3 Transport

Gujarat has a total railway length of 5564 kms which is approximately 9% of the total for India. Total surfaced roads in Gujarat at 41634 kms contribute to 5.7% of total roads in India. The share of national highways in this is 3.42% whereas the share of state highways is about 22.1%. Figure 1 gives the number of motor vehicles that have been registered as well as the number of motor vehicles actually on road by type of vehicle for three years - 1971, 1981, 1984.

Figure 1:Vehicles registered and on road



Except in the case of the Gujarat State Road Transport Corporation very little data is available on either passenger or freight transportation within the state of Gujarat. Gujarat State Road Transport Corporation provides detailed statistics on services provided both in mofussil areas as well as city services. Table 4 gives the important statistics in relation to GSRTC.

Table 4: Transport Statistics

Mofussil services	
Total number of buses	7781
Fleet utilisation	82.6%
Vehicle utilisation	310 km/day
Average sitting capacity	58.1
Load factor	75%
Passenger kms/litre	4.9
Passenger/day	37.02 lakhs
City services	
Total number of buses	543
Fleet utilisation	81.6%
Number of buses on road	443
Vehicle utilisation	171.6 kms/day
Average sitting capacity	58.1
Load factor*	80%

* assumed.

2.0 ENERGY RESOURCES SITUATION

2.1. Power

Since the inception of Gujarat state in May 1960, substantial resources have been diverted towards the development of the power sector which has resulted in the installed capacity increasing about ten fold in the 25 year period, 1960-61 to 1984-85. The progress that has been made since 1960 is summarized in Table 5 below.

Table 5:Progress of electricity supply

Year	Installed capacity MW	Gen. M.Units	Units Sold M. Units	Villages electrified number	Pumps energised no.
1960-61	315	546	441	823	5401
1970-71	879	2976	2346	4087	67052
1979-80	2384	8255	6244	10867	202853
1984-85	3383.5	12312	8504	16135	292387

The Working Group on power development in the Seventh Five Year Plan has estimated a power demand of 4038 MW in Gujarat by 1989-90 - which requires an installed capacity of 7647 MW. This would require an additional capacity installation of 3363.5 MW. If units likely to be replaced were taken into account additional capacity requirement in the Seventh Five Year Plan period alone would be 3882 MW. As against this total installed capacity in Gujarat as on 1.1.89 was 4399.5 MW which include 428 MW as its share from central sector projects. Projects that are likely to yield benefits in the remaining part of the Seventh Plan period amount to a further 400 MW.

Table 6 gives the distribution of hydro power potential in the country. As seen from the table Gujarat has a hydro power potential of 410 MW - which is a mere .5% of total hydr potential in the country. 73.2% of the 410 MW potential has already been exploited against an all India average of 18.7%.

Table 6: Distribution of Hydro-power Potential

	Hydro-power potential at 60% load factor		Installed hydel capacity as on March 1987	
	Million KW	%	MW	Installed capacity as % of potential
North-eastern region comprising Assam, Nagaland, Mizoram, Meghalaya, Sikkim, Arunachal Pradesh, Manipur and Tripura	33.45	38.8	307	0.9
Himachal Pradesh	11.46	13.4	2106(a)	18.4
Uttar Pradesh	9.73	11.4	1422	14.6
Jammu & Kashmir	7.48	8.7	176	2.4
Karnataka	4.87	5.7	2082	42.8
Madhya Pradesh	2.83	3.3	115	4.1
Andhra Pradesh	2.79	3.3	2442	87.5
Orissa	2.69	3.1	730	27.1
Kerala	2.31	2.7	1476	63.9
Maharashtra and Goa	2.20	2.5	1546	70.3
Tamil Nadu	1.97	2.3	1389	70.5
West Bengal	1.79	2.1	41	2.3
Punjab and Haryana	1.03	1.2	1255(b)	121.8(d)
Bihar	0.54	0.6	254(c)	47.0
Gujarat	0.41	0.5	300	73.2
Rajasthan	0.29	0.3	321	110.7(d)
All-India	85.54	100.0	15962	18.7

Notes: a. Includes Beas-Sutlej Link project even though only Punjab Haryana and Rajasthan will benefit by this project and Bilaspu plant of Bhakra (450 MW).

b. Includes Bhakra (104 MW).

c. Includes DVC (104 MW).

d. The actual is larger than potential because the actual capacit includes the projects located in other States and because th potential was under-estimated.

2.2. Oil and Gas

Until 1st January, 1986 only 558 MT of oil reserves were proved, 212 million tonnes in Gujarat and Assam together and 346 million tonnes in Bombay High. Of this 212 MT of proven reserves, Gujarat accounts for 98.64 million tonnes. Amongst the significant and major discoveries of the 1980s, the ONGC find at Gandhar in the Cambay basin of Gujarat ranks high. The discovery of oil at Gandhar was made in 1984 and the hydro carbon resources have been estimated at 400 million tonnes in an area of 800 sq. kms. Proven reserves of natural gas in 1986 were 497.05 billion cu.m (All India), of this 377.7 million cu.m. were established at Bombay High offshore and 119.36 billion cu.m. in onshore areas. Proven reserves in Gujarat in 1986 were 26.99 billion cu.m. i.e. 22.6% of onshore reserves. Table 7 gives the production pattern of oil and gas for the state of Gujarat and all India for some recent years. Gujarat also has a refinery situated at Koyali with a capacity of 4.1 million tonnes in 1986 which contributes 9.54% to total refining capacity in India (43 million tonnes).

Table 7: Crude Oil and Natural Gas Production

Year	Gujarat		All India	
	Crude oil ('000 tonnes)	Natural gas (Million cu.m.)	Crude oil ('000 tonnes)	Natural gas (Million cu.m.)
1970-71	3455	465	6822	1445
1971-72	3669	523	7299	1535
1972-73	3712	531	7321	1565
1973-74	3600	518	7189	1713
1974-75	3870	653	7684	2041
1975-76	4148	773	8448	2368
1976-77	4187	822	8898	2428
1977-78	4155	893	10763	2839
1978-79	4238	908	11633	2812
1979-80	3766	840	11766	2767
1980-81	3808	842	10507	2358
1981-82	3422	758	16194	3851
1982-83	3185	750	21063	4936
1983-84	3588	748	26020	5961
1984-85	3910	775	28990	7241
1985-86	4319	919	30168	8134
1986-87*	4561	971	30480	9853

* Provisional.
Source: Department of Petroleum.

2.3 Coal

Although very large coal reserves have been discovered in Gujarat these are at great depths (over 800 m) and thus are not mineable. While there is a proposal to carry out in-situ gasification this is still in the initial stages.

3.0 Energy Consumption Pattern In Gujarat

Per capita consumption of electricity in Gujarat increased from 138 kWh in 1970-71 to 294 kWh in 1985-86 - annual rate of increase of 5.2%. Per capita consumption of electricity at the all India level increased from 90 kWh to 176 kWh in the same period which rates an annual increase of 4.6% per annum. A sectorwise break-up of the per capita consumption of electricity is provided below.

Whereas in 1960-61, per capita power consumpiton in the domestic sector was a mere 3.5 kWh, this went up to 9.2 kWh in 1970-71 and further to 33.3 kWh in 1985-86. The all India per capita power consumption in 1985-86 was 25 kWh. Thus the annual rate of increase in the two periods in Gujarat works out to 8.1% and 9% respectively against the all India growth rates of 6.7% and 8.8% respectively.

Similarly, the agricultural sector has experienced fairly high growth rates increasing from 1 kWh per capita in 1960-61 to about 50.71 kWh in 1985-86. This again compares very favourably with all India consumption levels of 1.9 kWh in 1960-61 and 34.31 kWh in 1985-86.

Industrial consumption of electricity has also increased significantly. However, this has experienced much lower growth rates than in the other two sectors. Thus the per capita consumption in industry in 1960-61 was 39.1 kWh and went up to 189.7 kWh in 1985-86. All India industrial power consumption on the other hand increased from 22.1 kWh to 97.4 kWh in the same period. Thus although industrial power consumption in Gujarat on a per capita basis increased merely at approximately 4.8% per annum, this was significantly higher than the growth rate of 3.3% experienced at the all India level in the period

1970-71 to 1985-86. Table 8 gives energy consumption in Gujarat vis-a-vis India.

Table 8: Energy Consumption - Gujarat Vis-A-Vis India (1986-87)

Source of energy 8	Unit of consumption	Consumption		
		Total in India	Total in Gujarat	Gujarat as % of India
Petroleum products	Million TPA	43.7	-NA -(1)	-(1)
Coal	Million TPA	164.7	10.6	6.4
Natural gas	Million M^3/day	13.8	-Nil-(2)	-(2)
Electricity	Million kWh	174276	15431	8.9

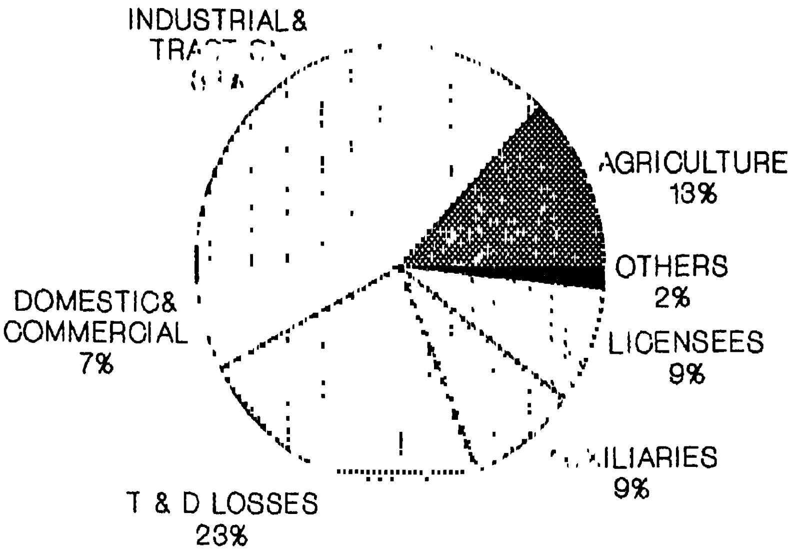
Source: Compilation from various sources.

Note :

1. The consumption of petroleum products in Gujarat during 1985-86 was 4.7 million tonnes, accounting for 11.5% of the total in the country.
2. The consumption in year 1985-86 was 2.2 MMM^3/day accounting for 16% of the consumption in the country.

Categorywise break up of electricity sales is provided in Figure 2. Thus we see that industry is the highest consumer of electricity followed by agriculture.

Figure 2.


BREAKUP OF ENERGY USED OUT OF TOTAL GENERATED AND PURCHASED

Sectorwise consumption of coal in Gujarat is given in Table 9. Thus we see that out of a total consumption of approximately 10.63 million tonnes in 1986-87, the power sector consumes nearly 70% of the coal. This is followed by cement with a share of 7.1%, chemical industries with a share of 6.5%, textiles 3.7%, fertilizers 3.5% and so on.

Table 9: Sectorwise Consumption of Coal in Gujarat

End-use sector	Consumption in 000 TPA in year		
	1985-86	1986-87	1987(Jan-Dec)
Power	6382.8 (61.6)	7405.9 (69.6)	8801.3 (72.0)
Cement	641.3 (6.2)	754.7 (7.1)	652.4 (5.3)
Chemical industries	609.5 (5.9)	693.1 (6.5)	615.4 (5.0)
Fertilizer industries	331.0 (3.2)	372.6 (3.5)	327.0 (2.7)
Ceramics	99.1 (0.9)	137.8 (1.3)	137.6 (1.1)
Textile/Rayon industries	807.2 (7.8)	394.0 (3.7)	938.3 (7.7)
Paper industries	100.3 (1.0)	99.3 (0.9)	88.1 (0.7)
Others	1389.1 (13.4)	777.3 (7.4)	666.2 (5.5)
TOTAL	10360.3	10634.7	12226.3

Source: Coal India Limited.

Note: Figures in brackets indicate consumption as % of total in a particular year.

Petroleum product consumption in Gujarat is given in Table 10. Thus, we see that Gujarat accounts for nearly 37% of LSHS consumption in India, 23% of LDO consumption, nearly 90% of naphtha consumption and a little over 10.3% of the fuel oil consumption. Total petroleum product consumption in 1984-85 was 4.73 million tonnes.

Table 11 gives the sectorwise consumption of natural gas in Gujarat. The major use of natural gas as yet is as a feedstock in the fertilizer and chemical industries. The power sector accounts for 20% of natural gas consumption in Gujarat.

Table 10: Petroleum Products Consumption In Gujarat (1984-85)

Product	Consumption (TPA)		
	Gujarat	India	Gujarat as % of total in India
ATF	36000	1337000	2.7
MS	178000	2086000	8.5
SKO	550000	5928000	9.3
HSD	970000	13462000	7.2
LDO	278000	1210000	23.0
FO	430000	4159000	10.3
LSHS	1343000	3631000	37.0
Naphtha	584000	3110000	18.8
LPG	80000	945000	8.5
Bitumen	93000	987000	9.9
Others	191000	1699000	11.2
TOTAL	4733000	38504000	12.3

Source: Indian Petroleum & Natural Gas Statistics.

Table 11: Sectorwise Consumption of Natural Gas in Gujarat (1984-85)

Sector	Consumption	
	MMM^3/day	As percentage of total consumption
Power	0.49	20.0
Feedstock	1.157	47.1
Energy source for Industries	0.76	30.9
Domestic fuel	0.05	2.0
TOTAL	2.457	100.0

Source: Gas Task Force Estimates.

Note: These figures pertain to gas consumed from on-shore fields of Gujarat. Subsequently, gas from Bombay High is being brought to Hazira to feed fertilizer units of M/s KRIBHCO as feedstock and fuel.

CHAPTER II : METHODOLOGY & STRUCTURE

In a developing economy it is necessary to plan for energy because:

- energy is an essential requirement for all economic activities and shortages of energy lead to serious retardation in other sectors of the economy;
- energy is a capital intensive sector, creating excess capacity is a gross misallocation of scarce funds. On the other hand, shortages can lead to heavy bridging expenditure.

As brought out in the previous chapter, the energy situation in Gujarat is rather alarming. With no production of coal, the state is currently consuming about 12 million tonnes of coal per annum moved over distances in the range of 800-1400 Kms. At the end of the seventh plan period the shortage in installed capacity is likely to be in the range of 2850 MW. While Gujarat produced 4.99 MT of crude oil in 1987-88, consumption of petroleum products has been provisionally estimated at 5.25 MT. The state is fortunate in having large reserves of natural gas and also in being located close to the western offshore fields of natural gas, however, the actual quantity of gas available to the state would depend on the share allotted to it. Given this energy situation, it is imperative to develop a long term energy strategy that would consider end-use demands for energy and the most optimal way of meeting these demands.

An integrated energy plan has been developed by TERI for the state of Gujarat taking into account resources available to the state, import requirements, infrastructure availability, desired rates of growth, demographic changes, costs and efficiences etc. Energy requirements upto the year 2010 have been estimated under alternative scenarios of development and resource availabilities. Substitution possibilities, energy conservation and renewable energy options have been taken into consideration.

1.0 Model Structure

The model can be looked upon as consisting of two separate parts (i) a Reference Energy System (RES) (ii) and a Linear Programming (LP) framework. The main features of this model are:

- it provides a simple mathematical representation of the energy flows in the economy.
- it accounts for conversion losses, transmission and distribution losses.
- it includes a linear programming part that draws upon the RES.

1.1 Reference Energy System

Figure 3 gives the RES that has been developed for Gujarat. The first column in the RES denotes resources and the last one the demand sectors of the economy. Energy flows, from a resource to a demand sector through extraction, refining and conversion and other stages, which are traced by taking into consideration energy losses at each stage.

The flow from the energy supply sectors to the non-energy sectors is routed through energy products where energy products are defined as energy end-uses. In other words, energy sources are first converted into the end uses for which they are being demanded by means of either device efficiencies or by looking at the relative effectiveness in case of more than one process. For example, kerosene consumed by the domestic sector is first converted to the end-use to which it is being put and would be represented as:

Kerosene -------> Cooking -------> Domestic Sector

1.2 Linear Programming Model

In the linear programming (LP) model the RES is viewed as a network optimization problem in which energy flows are routed through a linear network such that some objective function is optimized subject to the requirement that all end use demands are met. The objective function is specified as the minimisation of energy system costs :

$$\min \quad S = CX = \sum C_i X_i \quad \text{----------(iv)}$$

where C is a vector of unit costs and X is a vector of optimal energy required due to, say, the ith source i.e., cost for generating one unit of energy supply due to a source. The constraints set can be written as

$$\begin{aligned} G_1X_1 &= D \\ G_2X_2 &<= S \quad \text{----------(v)} \\ G_3X_3 &= 0 \end{aligned}$$

where D is a vector of end-use demands, S is a vector of supply constraints and the third equation represents all other network balances. The Gi represent corresponding coefficient matrices.

REFERENCE ENERGY SYSTEM FOR GUJARAT

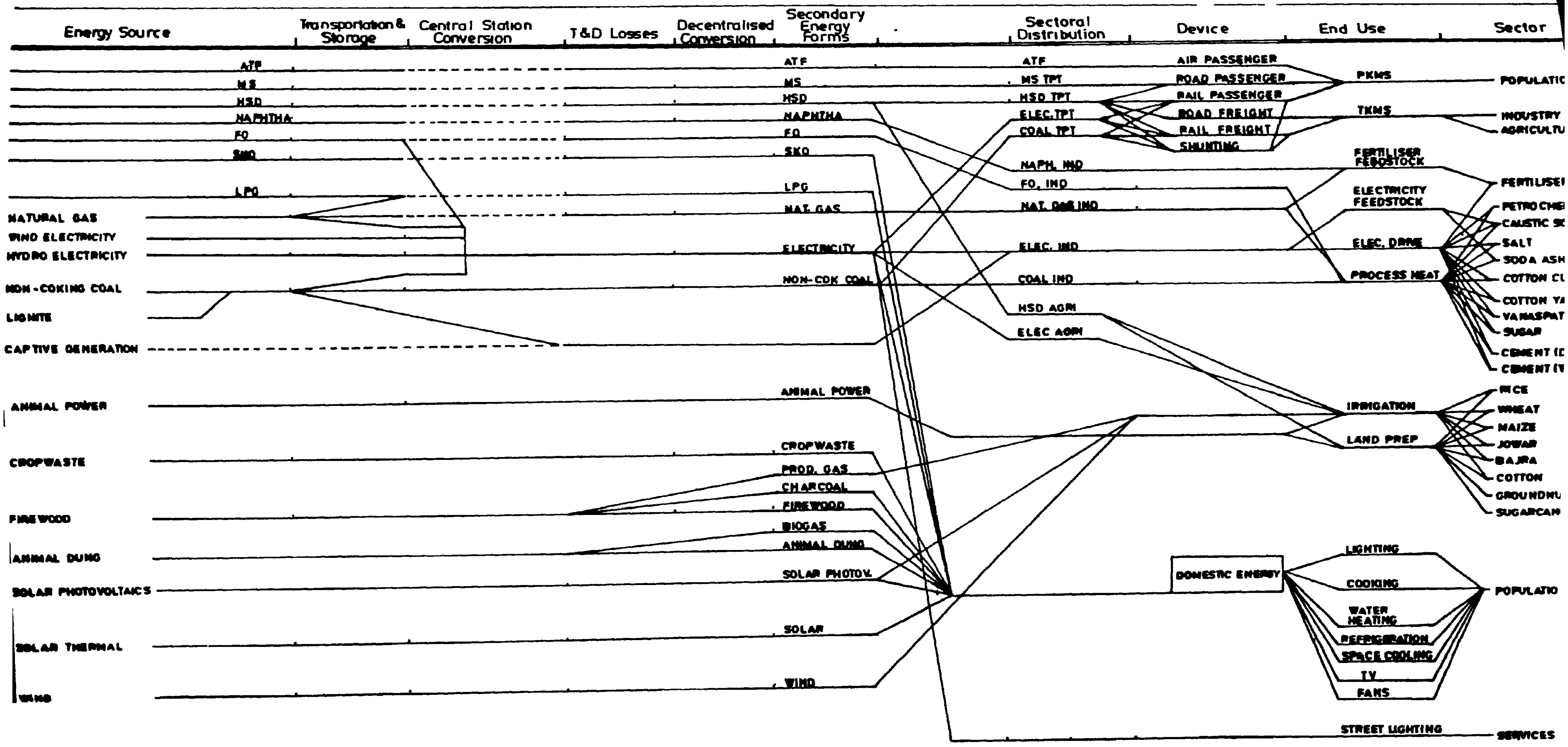


Figure 3

The equations forming $G_3X_3 = 0$ represent network balances and will have to be derived from the RES.

2.0 Constraints

The constraints in the model can be divided into six categories as shown below:

1. Population related energy demand and supply
2. Production related energy demand and supply
3. Electricity sector
4. Energy conversion and refining
5. Non-energy sector
6. Balance equations

2.1 Population related energy demand and supply

The total population has been divided into rural and urban categories which have been further sub-divided according to income classes. The per capita requirement of energy for cooking, water heating, lighting, cooling/heating and other purposes has been determined for each sub-category. This constitutes the population related energy demand and can be represented as:

$$\sum_{i=1}^{5} P_{ki}R_i + \sum_{i=1}^{5} P'_{ki}U_i = TD_k$$

where

i income category and $i = 1,2,3,4,5$

R_i rural income class i

U_i urban income class i

P_{ki} per capita energy demand for end-use k by the i^{th} income class of the rural population

$_{ki}$ per capita energy demand for end-use k by the i^{th} income class of the urban population

TD_k total energy demand for end-use k

The total energy demand for a particular end-use can be met using different devices. For example, the cooking energy demand for the urban households can be met using coal, kerosene, electricity, LPG or firewood. However, each fuel has a different efficiency, fuel cost and device cost. The supply set of constraints to meet the total energy demand for end-use k (TD_k) are :

$$\sum_{t} \eta_{kt} \; F_{kt} = TD_k$$

where

$_{kt}$ is the efficiency of fuel t used for energy end-use k

F_{kt} is the utilisation of fuel type t used to meet the energy end-use k

2.2 Production related energy demand and supply

The production sector can be broadly separated into three categories - agriculture, industry and other services. In agriculture, related to every crop there are energy requirements for irrigation and land preparation which can be met using different energy sources.

Industry has four energy end-uses - electric drive, fertilizer feedstock, process heat and electric feedstock. Other services would include public waterworks, street lighting, transportation, construction and other commercial services.

Associated with a unit output from each sector there is a requirement for one or more energy end-uses, thus the energy demand by the production sector can be presented mathematically as:

$$\sum_i P_{ki} C_i = ED_k$$

where

P_{ki} is the k^{th} energy end-use required for production of one unit of the i^{th} good

C_i is the total production of the i^{th} good

ED_k is the total demand for the K^{th} energy end-use.

The total demand for each energy end-use can be met using different energy sources. For example, the process heat requirements can be met using coal, furnace oil or natural gas. Another set of constraints represent the options available to meet the total energy end-use demand.

$$\sum_t \beta_{kt} F_{kt} \geq ED_k$$

where

β_{kt} is the efficiency of the t^{th} fuel for end-use k

F_{kt} is the total use of the t^{th} fuel for end-use k

ED_k total energy demand for end-use k

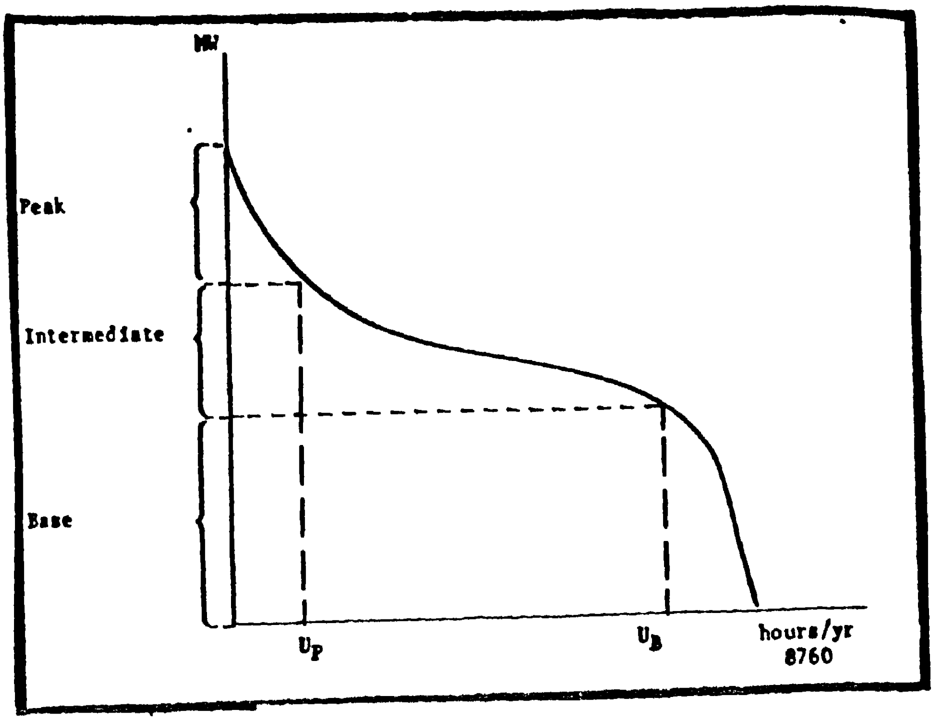
2.3 Electricity sector

The electricity sector has certain unique characteristics in that while it is the energy in kWh that is consumed capacities are measured in terms of MW which can be set-up in the form of either thermal, gas, diesel, hydro or nuclear power stations.

Also, the concept of peak load makes the modelling of this sector slightly difficult.

The starting point for analysis of the electricity sector is the load duration curve which characterizes the fraction of time for which the electrical load in a given system is greater than or equal to a particular output level. Figure 4 depicts an annual load duration curve, plotting systemwide demand (in MW) against the number of hours per year for which that demand

Figure 4. Optimal Generation Mix



is attained. Generation capacity must be sufficient to meet this demand: the basic question being what types of capacity should be built. Clearly, if we only built one type, say, oil fired plants, then for much of the year those plants would be sitting idle. The more expensive the initial capital cost, the less desirable it is to have a plant sitting idle: and hence we might wish to meet some parts of the demand curve with capacity that is less expensive. We would even be willing to settle for less efficient equipment to serve the peak hours, since such equipment would not be in operation very frequently. The basic trade-off, then, is between capital intensive, generally fuel efficient plants (exemplified by nuclear or large fossil fueled steam electric plants) and relatively cheaper, but usually less efficient capacity to serve the peaks, or "peaking plants".

For application to linear programming models one must linearize the load duration curve in the manner shown in Figure 4. Generally for the type of indicative planning that might use LP approaches, four or five segments suffice. In this model, we have limited ourselves to three sectors, identified as base, intermediate and peak modes. Note that the segmentation is horizontal, rather than vertical.

The generation requirements by the utilities is given by the following equation:

$$\sum_i ed_i = (1 - t)\, TE$$

where

ed_i is the electricity consumption by the ith sector

t is the transmission and distribution loss

TE is the total electricity generation requirement

The total electricity generation is related to the peak load (PL) using the shape of the load curve for the country.

$$PL = \alpha TE$$

where

α represents relationship between peak load and total generation requirement.

The electricity generation in each mode is a function of the peak load

$$DE_i = \theta_i PL$$

where

DE_i is the electricity generation in the i^{th} mode where i = peak, intermediate, base

θ_i is the constant which represents the relation between PL and DE_i

The generation requirements of the different modes can be met by different types of electricity plants and can be represented as:

$$DE_i = \sum_k T_{ik}$$

where

DE_i Electricity generation in the i^{th} mode (net of auxilliary consumption)

T_{ik} is the generation by plant type k for the i^{th} mode

The generation requirements by type of plant and mode is related to the capacity of different types of plant by taking into account the PLF in each mode and type of plant used.

$$TC_k = \sum_i Y_{ik} T_{ik}$$

where

TC_k is the total capacity of plant type k

Y_{ik} is the inverse of the PLF associated with plant type k generating in the i^{th} mode

T_{ik} is the generation by plant type k for the i^{th} mode

i peak, intermediate and base modes

k gas, coal, lignite, nuclear, hydro or diesel plants

2.4 Energy conversion/refining constraints

This set of constraints will incorporate the conversion of primary energy into secondary energy (eg. coal used for electricity generation) and the refining of energy sources (eg. oil refinery products). These include the fuel consumption norms, the refinery configuration and the conversion losses.

2.5 Balance Equations

$$\sum_k F_k = S_k + I_k - X_k$$

F_k - total demand for fuel k

S_k - domestic production of fuel k

I_k - imports of fuel k

X_k - exports of fuel k

The balance equations ensure that total availability of the different energy sources meet the demand generated by the system.

The above formulation of an LP problem though rather simplistic, has the flexibility to be extended to cover other issues. Most important amongst these is the inclusion of capacity and capital variables. The addition of an equation of the type

$$G_4X - G_5W \leqslant \overline{W}$$

where W is a vector of capital stock additions (denominated in capacity units -- bbls/day, Mw (e), and so forth) and $\overline{W}$ a vector of existing capital stocks takes care of the capacity variables. The objective function then becomes

$$\min S = cX + CRF\,\overline{\pi}\,W$$

where π is a vector of capacity costs (monetary units per unit of capacity), and CRF is the appropriate capital recovery factor.

A further refinement is the addition of a capital constraint, which has the rather simple form.

$$W \leqslant C$$

where 'C' is the capital limitation

3.0 Interpretation of the shadow prices associated with the LP

The dual of such a linear programming problem has important policy implications. Associated with every linear programming problem, the primal, is another LP known as the dual; if the primal is a minimization problem, the resulting dual is a maximization problem. Thus, if the primal is

$$\min z = \underset{(1xm)}{C^T}\ \underset{(mx1)}{X}$$

$$\text{s.t.}\quad \underset{(n\times m)}{A} \quad \underset{(m\times 1)}{X} \leq \underset{(n\times 1)}{b}$$

$$X \geq 0$$

then the dual is

$$\max z = \underset{(1\times n)}{b^T} \cdot \underset{(n\times 1)}{\lambda}$$

$$\text{s.t}\quad \underset{(m\times n)}{A^T} \quad \underset{(n\times 1)}{\lambda} \geq \underset{(m\times 1)}{C} \;;$$

$$\lambda \geq 0$$

Note that there is one dual variable for each row in the primal. From this immediately follows that there is a non-zero dual variable associated with each binding constraint in the primal: these are, of course, the shadow prices with respect to the resource or end-use demand constraint in question. Thus associated with the right-hand side vectors of the primal, D, S, and C are the corresponding vectors of shadow prices, say λD, λS, and λC.

How then are the various shadow prices to be interpreted? The λD represent the partial derivatives of the primal objective function with respect to the magnitude of the end-use demands. Comparison of the magnitudes among the λD therefore offers guidance as to where conservation will be most cost-effective and may pinpoint the sectors where government action may be the most important. One can also compare the magnitude of the shadow price with the unit cost of the conservation measure, say CDi. Conservation investments are justified in all instances for which

$$\lambda_{Di} \gg CDi$$

Indeed, it can be argued that even in a full market economy, such a condition would warrant a government conservation policy, especially where conservation benefits might be insufficient to warrant the investment when seen only from the standpoint of the end user.

The value of the shadow price associated with the capital constraint, λ_C, is of interest for overall development planning; it tells us something about the return on capital investment in the energy sector, and should be compared to the shadow prices for other non-energy sector investment opportunities.

The $_S$ represent the value of additional domestic energy resources to the energy system: if we have bounded supplies at the currently sustainable level, then the value of λ_S is to be compared to the cost of the next increment of supply (the next step in the supply curve). Where we use a supply curve step function in the analysis, the optimal level of supply development will be given by the solution itself; and unless we run into an absolute upper bound on resources, the corresponding shadow prices will be zero. Even more important policy guidance emerges from a comparison of the λ_D and λ_S; priority should be given to supply enhancements or to conservation investments emerges directly from a ranking of the respective shadow prices.

4.0 Objective Function - Costs

The model has been set up for short-term and medium term analysis. The objective function of the model is the cost minimisation of all forms of energy and energy utilising devices. In mathematical notation the objective function for the short-term would be:

$$\text{minimise} \quad S = \sum_{i} C_{xi}X_i + \sum_{j} C_{yj}Y_j + \sum_{k} C_{sk}S_k + \sum_{i} C_{il}I_l + \sum_{n} C_{En}E_n \qquad \ldots.(1)$$

where

C_{xi}	the non-fuel operating and maintenance cost of converting energy form X_i
X_i	the intermediate energy
C_{yj}	the non-fuel operating and maintenance cost of the end-use device Y_j
Y_j	End-use device utilisation
C_{sk}	non-fuel operating and maintenance cost of energy source S_k
S_k	domestic supplies of energy where k = coal, gas, crude oil, firewood, crop waste, dung etc.
C_{Il}	cif cost of imported fuel I_l
I_l	imports of energy sources
C_{En}	non-fuel operating and maintenance cost for electric plants
E_n	electric plants of type n where n = hydro, gas , coal, lignite, nuclear and diesel

The capital investments for the short run are taken as sunk costs as the capacity has already been set-up. Thus for 1985-86 only the operating and maintenance costs are considered. The objective function for a longer time horizon will also include the capital costs of setting up energy facilites. The investments for all types of capacity are annualised over the life of the plant using an appropriate discount rate. For 1994-95, 1999-2000 and 2009-10 the objective function is the following:

$$\text{Minimise} \quad S = \sum_i C_{xi}X_i + \sum_j C_{yj}Y_j + \sum_k C_{sk}S_k + \sum_i C_{Il}I_l + \sum_n C_{En}En + \text{CRF}(i,n)\left\{ \sum_x \pi_{xm}\bar{X}_m + \sum_j \pi_{yj}\bar{Y}_j + \sum_k \pi_{sq}\bar{S}_q + \sum_n \pi_{Er}\bar{E}_r \right\} \quad \ldots\ldots.(2)$$

where

C_{xi}, X_i, C_{yj}, Y_j, C_{sk}, S_k, C_{Il}, I_l, C_{En}, E_n as in equation (i)

CRF(i,n) is the capital recovery factor (for interest rate i and amortization period n)

π'_{ji} is the capital cost for the corresponding capital stock variable j_i

In this objective function the first part is the same as in equation (1) and the second part has been added to cover the capital costs associated with new capacity.

5.0 Bounds

Some variables have a lower and/or upper limit to make the model representative of the economy.

All primary energy sources have been given an upper bound. Existing capacity in certain sectors has been given an upper and lower bound as it is unlikely that given more efficient new technology all old capacity will remain unutilised. Suitable adjustments have been made for depreciation from time to time.

CHAPTER III : SECTORAL COMPOSITION AND DATA ASSUMPTIONS

1.0 Non Energy Sectors

The non-energy sectors that are important to Gujarat have been included in the model. These along with energy supply sectors are listed in Table 12. The growth rates that have been assumed for the different sectors are detailed in the same table. These growth rates have been corrected, as far as possible, to take into account perceptions of the Industries, Mines and Energy Department, Gandhinagar as well as those of the Industrial Extension Bureau, Ahmedabad.

Table 12: List of Sectors included in the Gujarat Model and Production ('000' Tonnes)

Sector	1985-86	2009-10	Average Annual Growth
Non Energy Sector			
Rice	454.2	1037.1	3.5
Wheat	782.8	3882.5	6.9
Maize	114.3	232.4	3.0
Jowar	235.0	500.5	3.2
Bajra	634.8	1449.5	3.5
Cotton	337.0	1086.8	5.0
Groundnut	448.0	755.3	2.2
Sugarcane	6489.6	59865.6	9.7
Sugar	470.0	1903.0	6.0
Salt	6567.4	13350.2	3.0
Vanaspati	82.3	333.2	6.0
Cotton yarn	124.2	400.6	5.0
Cotton cloth	581.4	1875.1	5.0
Soda ash	848.0	5377.3	8.0
Caustic soda	345.0	2111.7	5.0
Cement	2345.0	11586.0	8.0
Fertilisers	2700.0	4681.0	2.3
Petrochemicals	578.0	3665.2	8.0

Agricultural growth rates have been based on the compound growth rates for the different crops for the period 1960-61 to 1982-83. Adjustments have been made wherever necessary to incorporate the likely impact of the Sardar Sarovar Project on agricultural outputs.

2.0 Energy sectors

The domestic (State) primary energy supply resources that have been considered include hydro electricity, nuclear electricity, natural gas, oil, firewood, crop waste, animal dung, draught animal power, solar energy and wind power. However, import options are available for all the petroleum products as well as for non coking coal.

As regards the petroleum products that are available to Gujarat, it was assumed that a certain percentage of total Indian refinery capacity's output would be allotted to the state of Gujarat and this percentage was determined by taking into account current consumption of petroleum products and current refinery output. However, sensitivity analysis could be carried out on the impact of different percentage allotments on the development of Gujarat state.

The percentage allotments for different products for the year 1984-85 by the above calculations are listed below:

	%
LPG	6
Naphtha	17
Motor spirit	8
ATF	3
Kerosene	16
High Speed Diesel	6
Light Diesel Oil	22
Fuel Oil	12

For electricity an average annual load duration curve was estimated and the total electricity demand was divided on this basis into base, intermediate and peak energy demands. Appropriate relationships were developed to estimate peak load from total electricity demand that would be generated by the model as well as demands in the base, intermediate and peak modes.

Data on current natural gas availability and utilisation pattern was obtained from the papers that were presented at a seminar on "Natural gas - Its Impact on the Economic Development of Gujarat", organised by the Gujarat Foundation for Development Alternatives.

Total animal dung availability was estimated on the basis of current livestock population in the state of Gujarat. Similarly crop residue available was estimated by taking into account the qualities and mix of crop production.

Fuel availability assumptions for the year 2009-2010 are as given below:

For the petroleum sector the above percentage allotments have been assumed taking a total refinery capacity of 60 million tonnes {based on outputs from the TERI Energy Economy Simulation & Evaluation (TEESE) Model}.

In the case of coal, it has been projected that annual national production in the year 1999-2000 would be 417 million tonnes. Over the next 10 years an average annual growth rate of 1.5 per cent has been assumed which takes total national coal production to approximately 485 million tonnes. The calorific value of coal has been taken at 3200 kCal/kg. Coal consumption in Gujarat as a percent of total national consumption in 1985-86 was about 7.5%. Taking the same percentage allotment, coal availability to Gujarat was restricted to 33.95 MT.

The availability of natural gas from presently producing onshore fields is expected to go up from the current level of 2.8 MMSCMD to about 6 MMSCMD by the year 1994-95. Similarly, production from the Gandhar field is expected to be in the range of 8 MMSCMD in 1994-95. Assuming the necessary infrastructure development, production from the Western Offshore region is expected to be in the range of 60-65 MMSCMD taking the total gas availability in the western region to well over 75 MMSCMD in 1994-95.

For power generation capacities, power plants that have been sanctioned and cleared upto the VIIIth Five Year Plan period have been taken into account and set as lower bounds in the model. Table 13(a) gives details of the Installed capacity in

Gujarat as on 1.1.1989 and Table 13(b) gives a statement showing the list of approved and on-going schemes. Thus thermal capacity has a lower bound of 4392 MW and total hydel capacity has been assumed to be 772 MW. The Sardar Sarovar Project is expected to result in a total power generation capacity of 1450 MW of which 16 per cent is the share alloted to Gujarat.

Lignite production has been kept constant at 1.5 million tonnes per annum at a calorific value of 2800 kCal/kg. Lignite reserves in and around Kutch district are estimated at 200 MT in an area more than 45 sq.km. Ultimate production capacity from this will be 1.5 MT/annum as against current production level of about 0.7 MT/annum. Significant lignite reserves have also been found in Bhavnagar. However, lignite reserves in this field are somewhat isolated except in the Western part of the field which contains about 25% of the estimated reserves i.e. 21 MT.

Very large underground coal reserves have been found in Gujarat although at depths of over 800 metres. If R & D efforts on coal gasification at these depths is successful it is expected that some 15000 BCM of coal gas would be available to Gujarat. However, coal gasification at these depths has not been attempted elsewhere in the world. While a pilot hole has been drilled in the Mehsana region to test the quality and flow rate of gas, this option has not been taken into account as no concrete data is yet available on costs, efficiencies, composition etc.

Table 13(a): Installed Capacity (Gujarat) in MW

Sr. No.	Name of the Project	Units X capacity in MW	Total capacity in MW
1	2	3	4
1.	Dhuvaran TPS	4x63.5 2x140 2x27	588.0
2.	Ukai TPS	2x120 2x200 1x210	850.0
3.	Ukai Hydro	4x75	300.0
4.	Ukai L.B.C.	2x2.5	5.0
5.	Gandhinagar TPS	2x120	240.0
6.	Wanakbori TPS	6x210	1260.0
7.	Utran TPS	3x15 3x7.5	67.5
8.	Shapur		16.0
9.	Kandala		15.0
10.	Sikka TPS	1x120	120.0
11.	A.E. Co.	8x15 2x30 3x110 1x30	510.0
SHARE			
1.	Tarapur APS		190.0
2.	Korba STPS		200.0
3.	Vindhyachal STPS		38.0
	Total (as on 1.1.1989)		4399.5

Table 13(b) : Approved and Ongoing Schemes

VII PLAN PERIOD

1)	Kutch Lignite TPS - Unit - 1	70 MW
2)	Gandhinagar TPS Unit - 3 Extn.	210 MW
3)	Kadana Hydro Project Unit-I	60 MW
4)	Kadana Hydro roject Unit-II	60 MW
		400 MW

VIII PLAN PERIOD

1)	Gandhinagar TPS Unit - 4 Extn.	210 MW
2)	Kutch Lignite TPS Unit - 2	70 MW
3)	Sikka TPS Unit - 2 Extn.	120 MW
4)	Kadana Hydro Unit - 3 Extn.	60 MW
5)	Kadana Hydro Unit - 4 Extn.	60 MW
6)	Kutch LIgnite TPS - 3 Extn.	70 MW
7)	Mini Hydro Schemes	8.6 MW
		598.6 MW

3.0 End-Use Energy Demands

The end-use energy demands that have been considered for different sectors and their estimation and units of measurement are given below:

Transport

Two end use requirements have been considered - demand for passenger transportation measured in passenger kms and demand for freight transportation measured in tonne kms. For lack of better information the same lead distances were assumed for the major commodities used in Gujarat as at the all India level assuming that this would compensate for the movement of commodities that are produced outside of Gujarat and moved to destinations either within Gujarat or destinations outside

Gujarat itself however, passing through Gujarat. Per capita passenger transportation requirements were estimated from data and methodology presented in the report "Estimation of Total Road Transport, Freight and Passenger Movement in India" submitted to the Deptt. of Surface Transport, Government of India. The stock of vehicles currently on road in Gujarat were obtained from reports of the Transport Department in Gujarat. As regards railway capacity, Gujarat accounts for 9% of the total track length in the country. The growth rates assumed for railways were: 8 percent for electric traction and 5.6 percent for diesel traction. Steam locomotives are gradually being phased out. Diesel based road passenger movement is expected to increase at an annual rate of approximately 4 percent.

Industry

The end uses that have been considered for industry include industrial process heating, electric drive, electricity as a feedstock and fertiliser feedstocks. Useful energy requirements for process heating, electric drive and electricity as feedstock were estimated from various reports of the National Productivity Council, the energy audit data collected for specific industries in the state of Karnataka and in one or two cases consumption norms have been taken from international statistics (summarised in Table 14). Demand for fertiliser feedstocks has been measured in terms of ammonia required and the efficiencies of different fuels have been measured in terms of kCal/tonne of ammonia produced.

Table 14 : Energy Consumption Norms in the Industrial Sector

Industry/End-use	Process Heat (useful energy) 10^3kCal/unit	Electric Drive 10^3 kCal/unit	Electric Feedstock 10^3 kCal/unit	Feedstock 10^3 kCal/unit
Sugar (tonne)	288.40	1.976		
Salt (tonne)	2.23	9.35		
Vanaspati (tonne)	1073.50	287.24		
Cotton yarn and cloth (m)	1.26	0.774		
Soda ash (tonne)	2149.2	238.8		
Caustic soda (tonne)	1758.89	60.0	2915	
Cement (Dry) (tonne)	940.0	120.78		
Cement (Wet) (tonne)	1300.0	98.76		
Fertilizers (tonne)				
- Naphtha feedstock	2717.4	234.94		3868.6
- Natural gas feedstock	2145.43	179.07		3057.15
Petrochemicals (tonne)	2983.81	1588.02		2507.4

Source: 1. Technology Evaluation and Norms Study in the Fertilizer Sector - PDIL

2. Industrial Energy Conservation 1986-87 IPCL - TERI Report

3. Karnataka Regional Sub-model

4. Energy Use and Energy Efficiency in UK Manufacturing Industry upto the year 2000 (Vol. II)

Agriculture

Only two major end use energy requirements have been considered for the agricultural sector which include irrigation and land preparation. Although data for these end uses for the crops grown in Gujarat was not available this was compiled for the same crops from other regions of India as an approximation. Thus land preparation requirements were measured in terms of tractor hours and animal pair days required per hectare of land under different crops and irrigation requirements were measured in terms of cu.m. of water.

Table 15: Agriculture - Inputs (Per tonne)

Crop	%age area irrigated 1985-86	Irrigation 10^3 cub.m. per tonne	Land preparation (T hrs) Tractor	(APD) Animal
Rice	43.9	12.54	3.63	7.28
Wheat	69.6	1.38	4.01	8.0
Maize	7.8	3.69	3.08	5.92
Jowar	3.66	3.64	3.08	5.92
Bajra	9.3	3.64	3.08	5.92
Cotton	31.9	4.056	3.64	6.76
Groundnut	11.5	1.412		
Sugarcane	115.9	0.04		

Domestic

Domestic sector was broken up into two broad categories - rural and urban households. Both of these were then sub-divided into five income categories and useful energy requirements were estimated for each of these categories for different activities. The activities considered here include lighting, cooking, water heating, air conditioning, refrigeration, TV loads and ironing. Per capita useful energy consumption norms that have been assumed are given in Table 16 below.

Table 16: **Annual per capita useful energy requirement for the domestic sector - 1984-85**

come tegory	Distribution (millions)	Space cooling (10^3kCal)	Lighting (lumen hrs)	Cooking (10^3kCal)	Heating (litres)	Refrigeration (10^3kCal)	TV (10^3kCal)	Fans (10^3kCal
ural	24.616							
	(34.78) 8.56	1.87	40	160	301.7			0.0
I	(27.60) 6.79	4.41	70	160	347.0			
II	(22.54) 5.55	10.64	105	160	500.0			
V	(13.45) 3.31	14.41	150	200	765.0			
	(1.63) 0.4	15.38	170	260	812.0			
rban	11.584					71.0		
	(11.66) 1.35	1.57	135	160	453		0	0
I	(25.21) 2.92	7.76	276	160	530		0	19.5
III	(31.24) 3.62	17.58	400	290	712		1.26	53.57
IV	(26.72) 3.10	31.75	520	230	915		41.69	121.36
V	(5.17) 0.6	37.22	604	270	1145		241.61	222.5

* Figures in brackets indicate percentages taken from Sarvekshana, Vol.IX, No.3, Jan. 1986.

Income category	Per-capita Monthly Expenditure (in Rs.)
I	0 - 50
II	50 - 70
III	70 - 100
IV	100 - 200
V	200 above

The population for Gujarat for the year 2009-10 was taken as 51.91 million. A migration of 0.96 percent per annum from the lowest income category to the higher income category was assumed. In other classes an upward migration at the rate of 2.66 percent per annum is assumed. A rural-urban ratio of 60 : 40 for the population has been taken for 2009-10.

CHAPTER IV : RESULTS OF RUNS

1.0 Results of Model Validation

The model as described in Chapter II was first used on data for the year 1985-86 for purposes of validation. The results that have been obtained from this run are summarised in Table 17 below. While hydel capacity was restricted at 175 MW total thermal capacity was limited to 3139 MW. Peak load on the system works out to a little over 2545 MW and total electricity demand at the consumers end is 10950 GWh. Electricity generation requirement at the bus bar, assuming 18% T&D losses, works out to approximately 13353 GWh. Non coking coal consumption in 1985-86 as per the model works out to 10.2 million tonnes as against an actual consumption level of 10.6 million tonnes in the year 1986-87. Natural gas consumption works out to 2.47 million standard cu.m./day. Break-up of petroleum product consumption is also given in Table 17 below. It is seen that LPG and kerosene consumption is much higher than actual consumption of these products. This may be due to a higher assumption on the useful cooking energy requirements of the population under various income categories and also due to our assumption on the availability of non commercial forms of energy. Naphtha consumption also works out to be lower than the actual consumption. As regards transport fuels, consumption of motor spirit in private vehicles is seen to be much higher than was actually consumed. Fuel oil consumption is seen to be significantly lower than the actual consumption as all industrial process heat requirements are being met by coal.

Table 17: Model results for 1985-86 .

	Model results 1985-86	Alternative estimates 1985-86
Peak load (MW)	2345.0	2145.0[1]
Electricity demand (GWh)	10950.0	10376.0[1]
Non coking coal (MT)	10.2	10.6[2]
Natural gas consumption (MMSCMD)	2.5	2.2[2]
Petroleum products (MT)	3.9	4.7[3]
LPG	103.0	80.0
Naphtha	320.0	584.0
MS	547.5	178.0
ATF	257.4	36.0
SKO	1013.3	550.0
HSD	1005.7	970.0
FO	463.0	1773.0

Notes: 1. 13th Annual Power Survey.
2. Refer Table 8.
3. Refer Table 10.

2.0 Summary Results for 1994-95 and 1999-2000

While the reference year for the study had been taken as 2010, energy demand estimates have been made for the years 1994-95 and 1999-2000 as well. A summary of these demands is given below :

	1994-95	1999-2000
Peak Load (MW)	4271	7228
Electricity requirements at bus-bar (GWh)	24320	41160
Non-coking coal	20	31.68
Natural gas (MMSCMD)	5	17.29
Petroleum Products (MT)	6.26	6.35

The 13th annual power survey estimates peak load for the two years at 5018 MW and 7104 MW respectively, while electricity requirements have been placed at 27159 GWh and 38449 GWh respectively. Coal and natural gas availability have been restricted to 20 MT and 5 MMSCMD respectively for the year 1994-95 but have been left unconstrained in 1999-2000.

Total petroleum product consumption is seen to virtually stagnate during the period 1994-95 and 1999-2000. This can be explained by the following two factors : (i) Diesel use in irrigation is substituted for by electricity (ii) Fuel oil use in industry is replaced by the use of coal.

Natural gas consumption increases significantly due to high consumption by the power sector - 11.9 MMSCMD.

3.0 Results of Runs for the Year 2009-2010

The base case model for the year 2009-10 was run assuming that coal and gas availability is not constrained. Thermal capacity had been assumed at a minimum of 4392 MW which is the capacity that has already been sanctioned/ cleared. Hydel capacity has been restricted as mentioned earlier at 772 MW. The growth rates that have been assumed for different sectors are listed in Table 12 in Chapter III. Population in the year 2009-10 has been taken at 5.19 crores.

Under this scenario total electricity demand works out to 46.81 TWh signifying an average annual rate of growth of close to 6.7%. Peak Load at the bus-bar works out to 10026 MW. A summary of energy demands is given in Table 18. Coal demand at 31.8 million tonnes implies an average annual rate of growth of 4.7%. Natural gas consumption requirement works out to 31.1 million cu.m./day and petroleum products to 5.94 million tonnes per annum. The low rate of growth of petroleum products is seen to be compensated by the very high rate of growth of natural gas demand.

Table 18: Projected Energy Demands - 2009-10

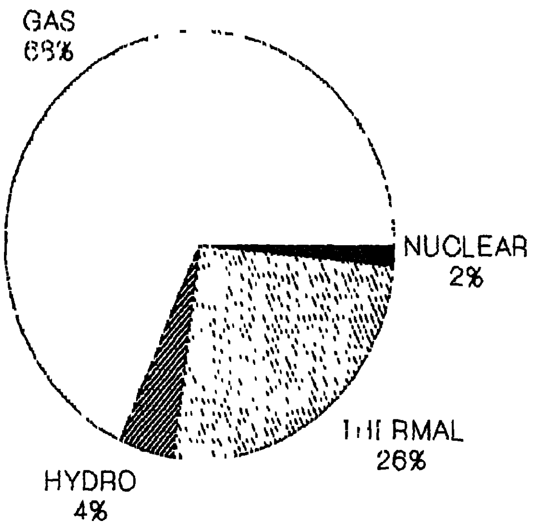
	2009-10	Annual %age increase over 1985-86
Electricity demand (GWh)	46813.8	6.7
Coal demand (MT)	31.8	4.7
Natural gas (MMSCMD)	31.1	11.3
Petroleum products (MT)	5.9	1.0

The gas based electricity generation capacity had been broken up into two different types - combined cycle that would provide power in the base and intermediate periods and open cycle that would provide power in the peak demand periods. Total gas based capacity that is indicated is 6705 MW of which 6360 MW is of the combined cycle type of power plants. Figure 5 gives the break-up of electricity generation by source .

Following is a break-up of the demand for various fuels by different sectors.

Electricity: Industry is seen to account for over 43% of total electricity demand. The household sector is seen to be the next major consumer of electricity accounting for nearly 23% of

Figure 5: Break-up of Electricity Generation by Source



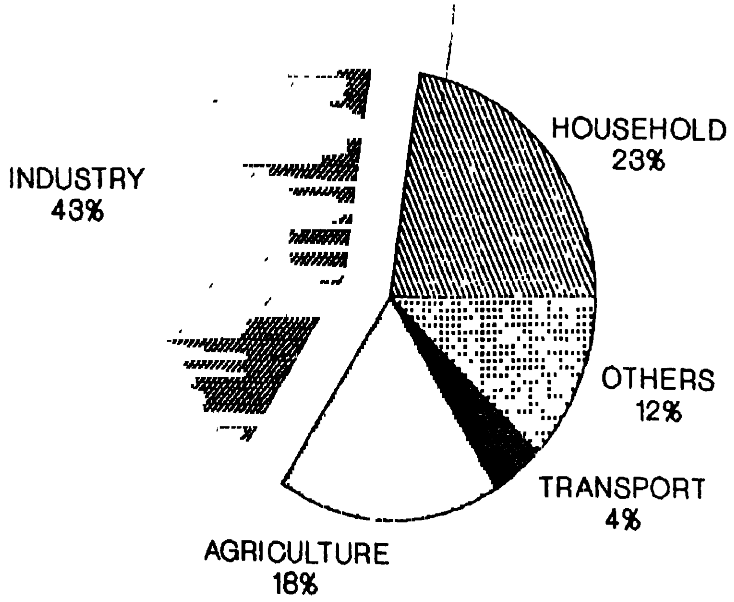
electricity demand. Agricultural consumption is seen to be slightly low at 8273 GWh accounting for nearly 18% of electricity demand. This share of electricity is low probably because of the following two reasons:

1. We have taken into account electricity requirements for irrigation alone.
2. We have assumed irrigation requirements in cu.m. of water as per the national averages.

The share of transport in total electricity demand has gone up significantly from around 2% in 1985-86 to 4.0% in 2009-10.

Coal: Coal demand is seen to be nearly 32 million tonnes. Assuming a national production of 485 million tonnes in the

Figure 6: Sectoral Break-up of Electricity Demand (2009-10)



year 2009-10 coal demand by Gujarat would account for nearly 6.6% of coal production in the country. 64% of this coal is seen to be consumed by the various industries for process heating purposes and the balance for power generation.

Table 19: Sectoral Composition (MT)

Sector	Coal	%
Industry	20.41	64.24
Power	11.36	35.76
TOTAL	31.77	

Petroleum Products: Transportation is seen to account for a little over 30.6% of total petroleum product consumption. Of the 1.82 million tonnes of petroleum consumed in the transportation sector 0.92 million tonnes is diesel consumption. Industry accounts for 35.4% of petroleum product consumption, nearly 47.5 % of which is naphtha consumed by the petrochemical and fertiliser industries.

Of the 1.61 million tonnes of petroleum consumption in the domestic sector, 1.39 million tonnes is consumed in the form of kerosene. Middle distillates consumption in the state o Gujarat is a little over 60% of total petroleum product consumption and conforms to the consumption pattern at the national level. The assumptions that have been made on percentage allotments to the state of Gujarat are listed in Chapter III. Under this scenario kerosene import requirements work out to 34 '000' tonnes.

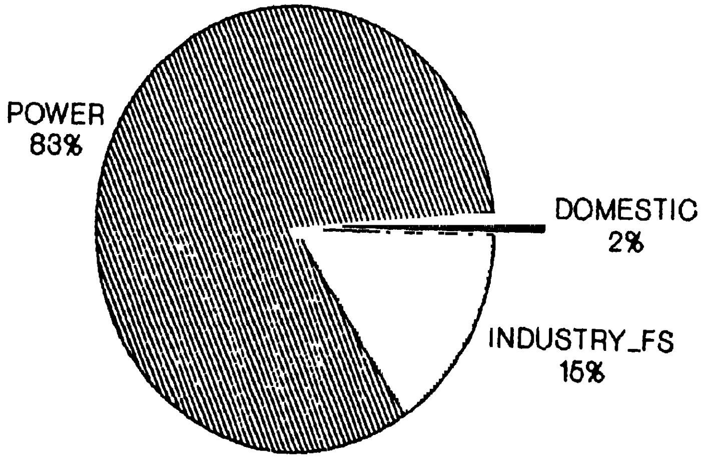
Table 20: Petroleum Products

Sector	'000'T	%
Industry	2103	35.4
Transport	1818	30.6
Domestic	1610	27.1
Agriculture	409	6.9
TOTAL	5940	100.0

Natural Gas: Of the total natural gas demand of 31.10 million cu.m./day 75.63% is accounted for by the power sector. Domestic requirement of natural gas works out to 0.5 million cu.m./day and the balance is consumed by the industrial sector as feedstock.

Figure 7:

SECTORAL CONSUMPTION OF NATURAL GAS IN GUJARAT IN 2010



3.1 Results from Alternative Scenarios for the Year 2009-10

Several scenarios had been run by making certain alterations in the scenario described above. These are explained and evaluated below. A summary of the results is given in Table 21 below.

Scenario I: Under this scenario upper bounds have been placed on availability of coal and natural gas to the state of Gujarat - 20 million tonnes and 10 million cu.m./day respectively. Peak load at bus bar comes down to 7955.8 MW and gas based capacity came down to 1632 MW. Total thermal capacity requirements go up to 7320 Mw and a wind generating capacity of 1314 MW is also indicated. Electricity import requirements work out to 13.98TWh.

While the demand for industry and household sector remains the same no electricity is now being consumed by the agricultural sector and demand by the transport sector is also reduced by about 6%. Irrigation demands are met by using diesel pumpsets. Total diesel consumption increases to 3.88 MT entailing imports of 2.55 MT. Although diesel consumption for transportation declined due to a decrease in total freight transportation within the state of Gujarat diesel requirements for irrigation increased tremendously from 0.4 MT to 3.07 MT. Diesel consumption for passenger transportation, however, increases to substitute for the lower electricity consumption for passenger transportation.

Due to the constraint on availability of coal, the consumption pattern is seen to shift with coal consumption by the power sector being significantly higher at 19.69 million tonnes and coal consumption by industry being drastically lower at 0.31 million tonnes. Out of the 10 million cu.m./day of natural gas consumption 5.21 million cu.m. is being consumed by for power generation purposes and the balance as a fertiliser feedstock As no natural gas is now being consumed by the domestic sector, kerosene consumption increases by about 12% thereby increasing kerosene imports to 0.20 million tonnes. Fuel oil imports are also indicated largely to meet the process heating requirements of industries at the very high level of 4.99 million tonnes per annum. Total freight transportation requirements have gone down from 94.4 BTKMS to 90.28 BTKMS. Total petroleum product consumption increases by almost a 140%.

Scenario II: Under this scenario we have removed the constraints on availability of coal. However, the gas availability has been constrained at 10 million cu.m./day. As a result total coal consumption goes up to almost 50 million tonnes and coal consumption for power generation purposes increases significantly to 28.86 million tonnes. Total thermal capacity goes up to 10731 MW and gas based generating capacity is 1641.5 MW of which 274 MW are utilised for peaking purposes and 1367.5 MW are for meeting the base and intermediate electricity demands. Actual peak load declines to 7956 MW.

Irrigation requirements are still being met through the use of diesel and freight transportation increases to nearly 111 BTKMS. The increased demand for diesel by the agricultural sector and for transportation purposes results in diesel imports going up to 3.05 million tonnes. Fuel oil import requirements declined to .06 million tonnes. While the domestic consumption of natural gas declines to 0.32 million cu.m./day, consumption by the power sector declines to 4.89 million cu.m./day. 1314 MW of wind based power generating capacity are still indicated in the model.

Scenario III: Under this scenario the reverse situation is taken whereby natural gas availability is left unrestricted. However, coal consumption is restricted to 20 million tonnes. Peak load declines marginally to 9779 MW and electricity demand to 45660 GWh. However, natural gas consumption goes up to 39.6 million cu.m./day of which 9.41 million cu.m./day are required by the industrial sector to meet its process heating requirements. Coal consumption by industry declines from 20.4 MT to 8.62 MT.

Scenario IV: Under this scenario we have assumed that total national refining capacity would go up from the originally assumed level of 60 million tonnes to about 70 million tonnes which would include the 3 million tonnes of refining capacity to be set up at Mangalore and some new capacity that would be required if domestic crude oil production were to reach the level of 75 MT. Again the electricity scenario remains more or less the same as in the base case. However, demand for petroleum product imports is reduced considerably with no imports of either kerosene, fuel oil, naphtha or high speed diesel. Total petroleum product consumption goes up by about 8%.

Scenario V: Under this scenario transmission and distribution losses have been increased to the present level of 24% as against an assumed level of 18% in the year 2009-10. This scenario would given an analysis of the impact of not improving the transmission and distribution losses. Peak load at the bus bar would go up to 11277.7 MW and the increased generation capacity requirements would all have to be met by increasing the gas based generation capacity which provides the cheapest option. No electricity imports or wind power generation are indicated. Consumption of natural gas goes up to 35.74 million cu.m./day reflecting the increase in natural gas consumption for power generation purposes (30.45 million cu.m./day).

Scenario VI : While in the base scenario we had assumed average lead distance for coal at 800 kms, in this scenario we increased it to about 1200 kms. Coal consumption declined marginally by about 2.7% and gas demand went up by 1.15 MMSCMD. No diesel is now being consumed for irrigation purposes although diesel demand for transportation goes up by 0.44 MT. The increased electricity demand for irrigation results in a 3% increase in total electricity demand.

Scenario VII : Efficiency improvements in energy use have been assumed in several industries ranging from 20-30%.

Peak load declines to 8790 MW and electricity generation requirements to 50057 GWh. Industrial electricity requirements are reduced to 15575.6 GWh.

The demand for coal works out to 27.24 MT as industrial consumption of coal goes down from 20.4 MT to about 15.8 MT. Demand for natural gas also declines to about 26.5 MMSCMD due to the lower consumption for power generation purposes (21.23 MMSCMD). Freight transport requirements are reduced by about 4 BTKMS.

Scenario VIII : The rate of growth of electric traction capacity has been assumed at 5% instead of 8% as in the base case.

Non-coking coal consumption declines from 31.77 MT to about 30.95 MT. This reflects the substitution of coal use for process heating by fuel oil use. Thus total fuel oil consumption increases from 510'000' Tonnes to about 714'000' Tonnes.

The reduction in electric freight movement capacity does not have a significant impact on coal movement but on the other hand the demand for road freight movement goes up by about 38.5%. Diesel demand for transportation goes up to 2.0 MT requiring imports of about 0.91 MT.

Scenario IX : Cogeneration is assumed to be feasible in the following industries : sugar, cotton textiles, basic chemicals and petrochemicals. Coal, fuel oil and natural gas based cogeneration options have been considered.

916 MW of coal based cogenerating capacity and 995 MW of natural gas based cogenerating capacity are indicated. Total electricity demand at the bus-bar and peak load on the system drops sharply to 34263 GWh and 6017 MW respectively. Total coal consumption declines marginally to 29.08 MT however, demand for natural gas drops significantly to 22.04 MMSCMD.

Freight transportation requirements drop from 94.42 BTKMS. Consequently demand for diesel for transportation reduces from 0.68 MT to about 0.60 MT. However, the demand for diesel for irrigation increases by the same amount substituting for electricity use in irrigation.

Scenario X : It has been assumed that the Gujarat economy will grow at an average rate of 6% per annum.

Peak Load at the system bus-bar works out to 14282 MW and energy requirements at 81,321 GWh. The industrial share in total electricity consumption goes up to 54.56% while the share of all other sectors declines. The additional capacity and generation requirements are met by using natural gas - the demand for which increases to nearly 41.5 MMSCMD. Total natural gas demand goes up to 47 MMSCMD.

Demand for non-coking coal goes up to 41.75 MT per annum. Of this 11.18 MT are consumed by the power sector and 30.57 MT by the industrial sector largely for meeting the process heat requirements.

The demand for diesel goes up to 1.884 MT (.51 MT of imports) of which nearly 87% is consumed for transportation purposes. Consumption of Naphtha goes up to 2.34 MT entailing imports of 1.16 MT. Total petroleum product demand goes up to 8.27 MT.

Table 21.

	2009-10	2009-10					
		SCENARIO I	SCENARIO II	SCENARIO III	SCENARIO IV	SCENARIO V	SCENARIO VI
Electricity							
Peak Load(at bus bar)	10026.44	7955.85	7955.81	9779.3	9866.2	11277.72	10337.9
Capacity (MW)							
Thermal	4392	7319.47	10731.28	4392	4392	4392	4392
Hydro - MW	772.0	772.0	772.0	772.0	772.0	772.0	772.0
Gas - CC	6359.9	1416.3	1367.4	6132.2	6212.22	7512.7	6646.9
- OC	345.0	215.9	274.1	336.9	339.9	388.5	356.2
Demand	57091.0	45300.6	45300.6	55683.2	56177.9	64215.4	58864.[illegible]
Household	10621.0	10621.0	10621.0	10621.0	10621.0	10621.0	10621.0
Industry	20218.15	20218.15	20218.15	20218.15	20218.15	20218.15	20218.15
Agriculture	8372.0	-	-	7383.03	7715.03	9649.2	9649.2
Transport	1893.0	1776.5	1893.0	1893.0	1893.0	1893.0	1893.0
Imports Electricity (GWh)	-	13986.3	-	-	-	-	-
Wind power (GWh)(Grid)	-	1314.0	1314.0	-	-	-	1293.5
Coal (MT)	31.77	20.0	49.27	20.0	31.78	30.90	30.94
Industry	20.41	.31	20.41	8.62	20.41	19.59	19.59
Power	11.36	19.69	28.86	11.37	11.37	11.30	11.35
Natural gas MMCMD	31.10	10.0	10.0	39.60	30.51	35.74	32.56
Domestic	0.5	-	0.32	0.5	0.5	0.5	0.5
Power	28.81	5.21	4.89	24.89	25.22	30.46	26.[illegible]
Industry-heat	-	-	-	9.41	-	-	-
-feedstock	4.79	4.79	4.79	4.79	4.79	4.79	4.79
Oil ('000' Tonnes)							
LPG	223.7	94.83	178.5	223.7	239.55	223.7	223.7
Naphtha	999.0	999.0	999.0	999.0	999.0	999.0	999.0
MS	606.3	606.3	606.3	606.3	606.3	606.3	606.3
ATF	292.24	292.24	292.24	292.24	292.24	292.24	292.24
SKO	1385.9	1551.1	1443.8	1358.9	1576.2	1385.9	1385.9
HSD	1329.9	3881.7	4645.9	1329.9	1551.6	1360.9	1362.9
FO	510.36	5703.1	772.2	714.36	510.5	714.36	714.36
Imports ('000' Tonnes)							
HSD	-	2551.8	3047.9	-	-	28.4	30.[illegible]
SKO	34.82	200.0	92.8	34.82	-	34.8	34.8
FO	-	4988.7	57.6	-	-	-	-
Naphtha	-	-	-	-	-		
BTKMS	94.43	90.29	110.92	85.15	94.76	106.25	106.30

	2009-10	2009-10			
		SCENARIO VII	SCENARIO VIII	SCENARIO IX	SCENARIO
Electricity					
Peak Load(at bus bar)	10026.44	8791	10052	6017.5	14282
Demand	57091.0	50057	57235.3	34263.74	81321.5
Household	10621.0	10612	10621	10621	10621
Industry	20218.15	15575	20218.15	4032.59	36387.5
Agriculture	8372.0	7951.22	9649.2	8122.5	9649.2
Transport	1893.0	1893	720.3	1893	1893
Imports Electricity (GWh) -					
Coal (MT)	31.77	27.24	30.95	29.08	41.75
Industry	20.41	15.82	19.59	8.68	30.57
Power	11.36	11.42	11.36	11.54	11.17
Cogenerating units		-	-	8.86	-
Natural gas MMCMD	31.10	26.52	31.19	22.04	46.88
Domestic	0.5	0.5	0.5	0.5	0.5
Power	28.81	21.23	25.91	10.95	41.60
Industry-heat	-	-	-	-	-
-feedstock	4.79	4.79	4.79	4.79	4.79
Cogenerating units		-	-	5.81	-
Oil ('000' Tonnes)					
LPG	223.7	223.7	223.7	223.7	223.7
Naphtha	999.0	999.0	999.0	999.0	2340.0
MS	606.3	606.3	606.3	606.3	606.3
ATF	292.24	292.24	292.24	292.24	292.24
SKO	1385.9	1385.9	1385.9	1385.9	1385.9
HSD	1329.9	1329.9	2324.5	1329.9	1883.9
FO	510.36	511.17	714.36	513.0	714.36
Imports ('000' Tonnes)					
HSD	-	-	914.17	-	509.22
SKO	34.82	34.82	34.82	34.82	34.82
FO	-	-	-	-	-
Naphtha	-	-	-	-	1162.23
BTKMS	94.43	90.81	94.61	92.28	120.37

CHAPTER V : Summary and Conclusions

Energy is an essential input into any economic activity. Thus the growth of an economy is dependent on its access to sufficient supplies of energy. While India has very large reserves of coal, Gujarat has limited benefits since these fields are located at large distances ranging from 800 kms. to 1400 kms. away. The hydro electric potential of the state is also rather limited. On the other hand, the state is located in the western region and has in its proximity very large reserves of oil and natural gas. However, the availability of these reserves to the state of Gujarat is rather uncertain and depends on the share allotted by the Government of India.

In this study, we have undertaken an end-use approach to estimate the quantity of energy that should be supplied to the state in order to ensure that it is able to maintain a satisfactory rate of growth. This quantity and the mix of energy that is required is estimated using a linear optimisation approach with the objective of minimising overall energy system costs. Since the demand for all forms of energy has been estimated in an integrated manner keeping in mind substitution possibilities, it is likely that the results may differ somewhat from other such exercises. The output that has been obtained from several runs of the optimisation model and the conclusions that can be drawn from these are summarised as follows.

Two sets of economic growth rates have been assumed for the state of Gujarat - 5% and 6%. Total population in the year 2010 has been assumed at 5.19 crores. The energy requirements under the two scenarios are given below:

	5% rate of growth	6% rate of growth
Peak Load (MW)	10026.00	14282.00
Electricity requirement (GWh)	57091.00	81322.00
Non-coking coal demand (MT)	31.77	41.75
Natural gas demand (MMSCMD)	31.10	46.88
Petroleum Product consumption	5.94	8.27

Renewable energy options of wind electricity generation and for irrigation pumping are generally not viable with existing technology. The wind based electricity generation is opted for only in the case where both coal and natural gas availability is constrained. Renewable options for pumping purposes are not viable due to the low water tables prevalent in Gujarat. The use of solar devices, other than the solar cooker, is also not economical at present costs and technologies.

While the share of industry in total electricity consumption in the 5% r.o.g. scenario is 43% this share increases to 54.5% in the 6% r.o.g. scenario.

If the availability of both natural gas and non-coking coal is restricted then natural gas is first seen to be utilised for meeting the requirements of the fertilizer sector and the balance is used for power generation purposes.

A large quantity of natural gas is required for setting up combined cycle power plants operating in the base mode. This is largely due to the fact that the amount of hydro and nuclear capacity available to the state is restricted and natural gas is a cheaper option as compared to setting up new thermal (coal-based) capacity.

For meeting the demands of industrial process heat the first option is that of coal. If coal availability is restricted for whatsoever reason then the next in order of preference is natural gas followed by fuel oil.

Irrigation energy requirements should be met by using diesel pumpsets as long as the diesel is obtained from domestic refineries. However, diesel is first utilised to meet the transportation and land preparation requirements. In other words, if out of the diesel allotted to the state of Gujarat, there is a certain quantity left over after meeting the transportation and land preparation requirements, then this quantity should be used as a substitute for electricity in irrigation pumpsets.

The use of cogenerating units in industry should be encouraged as far as possible. The cogeneration option was found to be desirable when considered for the sugar, cotton textiles, basic chemicals and petrochemicals industries. Most of the process heat and electric drive requirements of these industries were seen to be met through cogenerating units resulting in a decline in total primary energy consumption of the state by 15% (in the 5% r.o.g. scenario).

Assuming no limitations on the supply of coal and natural gas the demand for these fuels works out to 31.77 MT/annum and 31.1 million cu.m. per day respectively. However if the availability of coal were to be constrained to even 20 MT then the demand for natural gas would go up to nearly 40 million cu.m. per day. On the other hand if the availability of natural gas was to be restricted to 10 miilion cu.m. per day then the demand for coal would increase steeply to a little over 49 MT. At present the railway system in Gujarat is barely able to move about 12 MT of coal per annum and it is felt that the capacity to move coal may at best go up to about 15 MT per annum - which would further increase the demand for natural gas. The balance between coal and natural gas would have to be worked out carefully keeping in mind availabily of supply, infrastructural requirements, costs etc.

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